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(54) A radiant tube burner

(57) A radiant tube burner (10) comprising a burner tube, a fuel inlet (18) arranged to receive fuel from a supply (16) and to supply fuel to the burner, an air inlet for receiving combustion air, a mixing chamber (30) and a burner head (32), the fuel inlet being arranged to supply fuel to the mixing chamber upstream of the burner head and the air inlet comprising primary air inlet means (22) for providing a turbulent air flow into the mixing chamber upstream of the burner head and secondary air inlet (24) means for providing a substantially non-turbulent air flow downstream of the burner head.

A method of operating a radiant tube burner, the burner comprising a fuel supply, an air inlet, a fuel air mixing chamber and a burner head, the method comprising the steps of supplying fuel to the mixing chamber, providing a primary turbulent air flow to the mixing chamber to mix fuel and air, burning the fuel/air mixture at the burner head and providing a secondary substantially non-turbulent air flow downstream of the burner head.

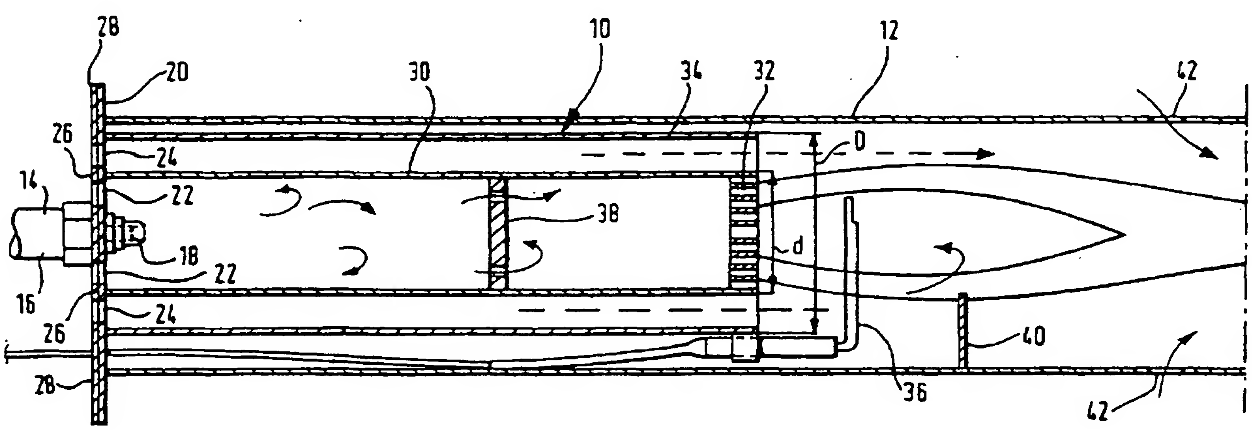

FIG.2.

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Description

[0001] This invention relates to a radiant tube burner primarily for use in heating large volume installations.

[0002] Known radiant tube burners for radiant tube heating arrangements generally comprise a burner head to which fuel, normally in the form of natural gas, is supplied under pressure and an air inlet orifice plate arranged around the burner head through which air is supplied to the burner. The orifice plate is arranged to induce high turbulence in the air flowing through it to promote mixing with the gas coming through the burner head. The mixing is required in order to produce combustion at the burner head. The high rate of mixing results in a short very high temperature flame which has a tendency to produce high levels of nitrogen oxides which are undesirable. Previous solutions to reduce nitrogen oxides (NOx) have tended to result in increased levels of soot formation. The high turbulence mixing also results in quite high levels of operating noise.

[0003] It is an object of the invention to provide an improved radiant tube burner with reduced NOx emissions.

[0004] According to a first aspect of the invention there is provided a radiant tube burner comprising a burner tube, a fuel inlet arranged to receive fuel from a supply and to supply fuel to the burner, an air inlet for receiving combustion air, a mixing chamber and a burner head, the fuel inlet being arranged to supply fuel to the mixing chamber upstream of the burner head and the air inlet comprising primary air inlet means for providing a turbulent air flow into the mixing chamber upstream of the burner head and secondary air inlet means for providing a substantially non-turbulent air flow downstream of the burner head.

[0005] In that way, a long flame is generated by the non-turbulent air flow while the turbulent mixing before the burner head prevents soot build-up. The longer flame reduces heat release, the peak flame temperature and hence NOx emissions. The longer flame also results in more even temperature distribution along the length of the heater which reduces the cost of tube material since a lower grade of material can be used.

[0006] Preferably, the mixing chamber comprises a tube upstream of the burner head, the end of the tube being closed by the burner head. The mixing chamber tube is preferably elongate, ie its length is greater than its diameter. Preferably the ratio of tube length to tube diameter is at least 3:1 and most preferably 5:1.

[0007] In a preferred embodiment, the air inlet comprises a plate having holes therethrough. Preferably the holes are of different sizes. Where the mixing chamber comprises a tube, the air inlet plate preferably comprises a first set of holes within the tube wall and a second set of holes outside the tube wall. In that case, the first set of holes may be arranged to promote mixing of fuel and air and the second set arranged to promote substantially non-turbulent air flow.

[0008] The fuel inlet preferably comprises an injector having a plurality of injector apertures. That helps to promote mixing before the burner head. The baffle may be provided in the mixing tube before the burner head to aid fuel/air mixing.

[0009] The secondary air flow is preferably formed as a substantially annular flow around the flame.

[0010] Where the mixing chamber comprises a tube, a further tube having a larger diameter than the mixing chamber tube may be provided around the mixing chamber tube. The further tube is preferably arranged concentrically with the mixing chamber tube. In such a case, the secondary air flow preferably travels between the two tubes. Where the air inlet comprises a plate having holes therethrough and the further tube is provided, the air inlet plate preferably comprises a first set of holes within the mixing chamber tube wall and second set of holes outside the mixing chamber tube wall and inside the further tube wall. The mixing chamber tube and secondary air flow tube are additional to the burner tube itself.

[0011] Downstream of the burner head, a baffle may be provided in the burner tube. The baffle is preferably located spaced from the burner tube so as to allow the secondary air flow to generate a long, "cool" flame.

[0012] In a preferred embodiment, in addition to the primary turbulent air flow and the substantially smooth secondary air flow, a tertiary air flow may be provided substantially downstream of the burner head so as to stage combustion air to the flame. In that way, the good mixing provided by the primary air promotes a good flame at the burner head, the secondary air promotes a long, "cool" flame with low NOx and the tertiary air flow completes the combustion downstream in the burner tube. Preferably, the tertiary air flow is turbulent to promote good mixing of fuel and air. The tertiary air flow is preferably provided by apertures formed in the burner tube spaced downstream from the burner head. The tertiary turbulent air flow may be effected by means of the aforesaid baffle in the burner tube causing turbulence in the smooth secondary air flow.

[0013] According to a second aspect of the invention there is provided a method of operating a radiant tube burner, the burner comprising a fuel supply an air inlet, a fuel air mixing chamber and a burner head. the method comprising the steps of supplying fuel to the mixing chamber, providing a primary turbulent air flow to the mixing chamber to mix fuel and air, burning the fuel/air mixture at the burner head and providing a secondary substantially non-turbulent air flow downstream of the burner head.

[0014] In a preferred embodiment of the method, the method comprises the further step of providing a tertiary air flow downstream of the secondary air flow. The step of providing the tertiary air flow preferably comprises the step of introducing further air into the burner tube downstream of the secondary air flow. In such a case the further air flow may be arranged to be turbulent. Alterna-

tively, or in addition to introducing further air, the tertiary air flow can be provided by disrupting the smooth secondary air flow by means of a baffle or the like.

[0015] The applicants have found that a burner made in accordance with the invention produces a reduction of approximately 15%-30% in NOx emissions while not promoting soot formation in the tube. The flame length in the present invention is approximately 30% longer than in conventional radiant tube burners which results in much more even temperature distribution along the length of the heater, a reduction in peak metal temperatures and consequent savings in tube material costs. The better temperature distribution also results in improved temperature distribution on the floor of an installation. The reduction in flame turbulence of the present invention results in a much quieter operation than known radiant tube burners.

[0016] The arrangement according to the invention produces a central core flame of low turbulence with a well mixed air/gas mixture burning on the burner head and an outer core of non-turbulent air providing sufficient air to complete combustion. In the most preferred embodiment the secondary air flow has substantially the same velocity as the flame to slow down the rate of mixing downstream of the burner head.

[0017] A radiant tube burner in accordance with the invention will now be described in detail by way of example and with reference to the accompanying drawing, in which;

[0018] FIG.1 is a cross-section through a radiant tube burner made in accordance with the invention arranged in situ on a radiant tube heater.

[0019] In FIG.1 a radiant tube burner assembly 10 is shown arranged in a pipe 12 of a radiant heater. The radiant tube burner assembly 10 comprises a gas supply 14 comprising a pipe 16 from a gas reservoir or gas mains (not shown). The pipe 16 terminates in a nozzle 18 which extends through an air inlet orifice plate 20 of the burner assembly 10. The nozzle 18 is preferably provided with multiple outlet apertures which promotes good mixing of gas and air and reduces NOx emissions. The air inlet orifice plate 20 has two sets of holes formed therethrough. The first set of holes 22 are arranged in a ring around the gas nozzle 18. The second set of holes 24 are arranged in a ring around the outside of the first set of holes 22. Between the first and second sets of holes 22, 24, the orifice plate 20 includes a solid annular piece 26. Air orifice plate 20 further comprises a second solid annular piece 28 around the outside of the second set of holes 24.

[0020] A first tube 30 having a first diameter d extends from the orifice plate 20. The diameter of tube 30 is substantially similar to that of the first solid annular piece 26 of the orifice plate 20. At the upstream end of the tube 30, the tube 30 abuts the first solid annular piece 26 of the orifice plate 20 in a substantially gas-tight manner. The downstream end of tube 30 is closed off by a burner head 32. The burner head 32 comprises a substantially circular plug which closes off the end of tube 30 having a plurality of holes formed therethrough to as to allow fuel/air mixture from inside tube 30 to pass air through and to be combusted. A second tube 34 having a diameter D is arranged around first tube 30. The larger diameter D is preferably 1.5-2 times greater than the smaller diameter d of tube 30. Although it is not necessary for the function of the invention, the tube 34 is preferably arranged concentrically with tube 30. The diameter of tube 34 is such that it abuts the second annular piece 28 of the orifice plate 20 in sealing fashion. The tubes 30, 34 are preferably identical in length. The second solid annular piece 28 of the orifice plate 20 is also abutted by the downstream end of pipe 12 in sealing fashion so that the only air which enters the burner enters through holes 22, 24. A baffle (not shown) may be arranged in the tube 30 upstream of the burner head 32 and downstream of the nozzle 18 to promote turbulence, and thus mixing of gas and air.

[0021] An ignition mechanism 36, either in the form of a pilot light or a spark generator is arranged downstream of the burner head 32 within the pipe 12.

[0022] The holes 22 are preferably dimensioned so as to create turbulent flow within tube 30 to promote good mixing of the fuel and air upstream of the burner head 32. The second set of holes 24 are dimensioned so as to reduce any turbulent effects and the length of tubes 30, 34 is also selected to ensure that a substantially non-turbulent airflow emerges from between the two tubes at the downstream end thereof around the burner head 32.

[0023] In use, gas is supplied through the pipe 16 and nozzle 18 into the interior of tube 30. Air is supplied under pressure, either by drawing air through pipe 12 by means of an impeller downstream of the burner or by blowing air through the orifice plate 20 by means of a fan upstream of the orifice plate. The pressurised air flows through the first set of holes 22 and the arrangement of holes 22 promotes turbulent air flow downstream thereof. The turbulent air flow promotes good mixing of the gas supplied through nozzle 18 into the tube 30 so that by the time the gas and air reach burner head 32 the two components are well mixed.

[0024] The air also passes through set of holes 24 which are intended to promote substantially non-turbulent conditions. That second air flow travels along the space between the outer wall of tube 30 and the inner wall of tube 34 and emerges from the tubes adjacent the burner head 32 in an annulus. The ignition device 36 ignites the fuel air mixture emerging through the holes in the burner head 32. The burner head 32 prevents the flame from chasing back up the pipe 30 towards the fuel supply. The provision of the good fuel air mix through the burner head and the substantially non-turbulent flow in an annulus promotes a long flame as shown in FIG.1.

[0025] Of course, it will be appreciated that turbulent effects cannot be eliminated altogether in the secondary air flow. However, the term "substantially non-turbulent"

should be taken in the context of the highly turbulent nature of the primary airflow within tube 30. Consequently, there will be inevitable turbulent effects at the border between the flame generated at the burner head 32 and the annular flow emerging from between pipes 30 and 34. However, it is intended that these effects should be reduced so as to create as little turbulence as possible downstream of the burner head.

[0026] The combination of highly turbulent mixing upstream of the burner head and low turbulent flow downstream of the burner head produces a tube burner with substantially reduced NOx emissions, lower levels of soot build up and reduced operating noise. The substantially longer flame (up to 30% than conventional burners) results in better and more even temperature distribution down pipe 12 which means that pipe 12 can be made from less highly specified material creating a substantial reduction in cost of the heater assembly as a whole.

[0027] The reduction in NOx emissions is environmentally beneficial and the reduced soot formation results in lower maintenance cost.

[0028] The burner head 32 can be of any suitable form, such as a "pepper pot", a fine flame arrester gauze or even a larger opening. Such a larger opening would give a slighter higher noise level however.

[0029] Although in the embodiment shown the burner is mounted inside the pipe 12, it could be mounted outside the pipe with just the burner head 32 protruding into the pipe 12 or mounted at the mouth of the pipe. That arrangement would result in slightly nosier operation and so the arrangement shown in FIG.1 is preferred.

[0030] For clarity, the direction of flow in the embodiment described is from the left hand side looking at FIG. 1 towards the right hand side. Consequently, references to "upstream" throughout the description shall mean "to the left" in FIG.1 while "downstream" shall mean "to the right".

[0031] FIG.2 illustrates an alternative embodiment of radiant tube heater in accordance with the invention. Parts corresponding to parts in FIG.1 carry the same reference numerals.

[0032] The burner of FIG.2 is substantially identical to that shown in FIG.1. In the FIG.2 burner a baffle 38 is arranged in the mixing tube 30. The baffle 38 promotes more effective mixing of the air and gas mixture within the mixing tube 30.

[0033] A further small baffle 40 is arranged in the main burner tube slightly downstream of the burner head 32. The baffle 40 creates a recirculation of the gas at the root of the flame which tends to reduce the temperature at which the flame burns and thus reduces NOx emissions.

[0034] Apertures 42 are provided in the wall of the main burner tube 12 substantially downstream of the burner head 32 and downstream of the baffle 40. The apertures 42 permit introduction of tertiary air flow. That tertiary air flow can be arranged to be turbulent so that a three-stage air flow is provided in the tube of FIG.2, namely a high turbulence primary mixing air flow within the mixing tube 30, a secondary substantially smooth air flow downstream of the burner head 32 to promote a long cool flame and a tertiary air flow through the apertures 42 which firstly introduces more air into the flow and secondary creates turbulence to promote burn out of the flame and improve mixing further down the tube. That also reduces the NOx emissions of such a burner.

Claims

1. A radiant tube burner comprising a burner tube, a fuel inlet arranged to receive fuel from a supply and to supply fuel to the burner, an air inlet for receiving combustion air, a mixing chamber and a burner head, the fuel inlet being arranged to supply fuel to the mixing chamber upstream of the burner head and the air inlet comprising primary air inlet means for providing a turbulent air flow into the mixing chamber upstream of the burner head and secondary air inlet means for providing a substantially non-turbulent air flow downstream of the burner head.

2. A radiant tube burner according to claim 1 in which the mixing chamber comprises a tube upstream of the burner head, the end of the tube being closed by the burner head.

3. A radiant tube burner according to claim 2 in which the mixing chamber is elongate, ie its length is greater than its diameter.

4. A radiant tube burner according to claims 2 or 3 in which the ratio of tube length to tube diameter is at least 3:1 and most preferably 5:1.

5. A radiant tube burner according to any preceding claim in which the air inlet comprises a plate having holes therethrough.

6. A radiant tube burner according to claim 5 in which the holes are of different sizes.

7. A radiant tube burner according to claim 6 in which, where the mixing chamber comprises a tube, the air inlet plate preferably comprises a first set of holes within the tube wall and a second set of holes outside the tube wall.

8. A radiant tube burner according to claim 7 in which the first set of holes is arranged to promote mixing of fuel and air and the second set arranged to promote substantially non-turbulent air flow.

9. A radiant tube burner according to any preceding claim in which the fuel inlet comprises an injector having a plurality of injector apertures.

10. A radiant tube burner according to any preceding claim in which a baffle is provided in the mixing tube before the burner head to aid fuel/air mixing.

11. A radiant tube burner according to any preceding claim in which the secondary air flow is formed as a substantially annular flow around the flame.

12. A radiant tube burner according to claim 2 in which a further tube having a larger diameter than the mixing chamber tube is provided around the mixing chamber tube.

13. A radiant tube burner according to claim 12 in which the further tube is arranged concentrically with the mixing chamber tube.

14. A radiant tube burner according to any preceding claim in which downstream of the burner head, a baffle may be provided in the burner tube.

15. A radiant tube burner according to any preceding claim in which a tertiary air flow is provided substantially downstream of the burner head so as to stage combustion air to the flame.

16. A radiant tube burner according to claim 15 in which the tertiary air flow is turbulent to promote good mixing of fuel and air.

17. A radiant tube burner according to claim 15 or 16 in which the tertiary air flow is provided by apertures formed in the burner tube spaced downstream from the burner head.

18. A radiant tube burner according to claim 15 when dependent upon claim 14 in which the tertiary turbulent air flow is effected by means of the aforesaid baffle in the burner tube causing turbulence in the smooth secondary air flow.

19. A method of operating a radiant tube burner, the burner comprising a fuel supply, an air inlet, a fuel air mixing chamber and a burner head, the method comprising the steps of supplying fuel to the mixing chamber, providing a primary turbulent air flow to the mixing chamber to mix fuel and air, burning the fuel/air mixture at the burner head and providing a secondary substantially non-turbulent air flow downstream of the burner head.

20. A method of operating a radiant tube burner according to claim 19 in which the method comprises the further step of providing a tertiary air flow downstream of the secondary air flow.

21. A method of operating a radiant tube according to claim 20 in which the step of providing the tertiary air flow comprises the step of introducing further air into the burner tube downstream of the secondary air flow.

22. A method of operating a radiant tube according to claim 21 in which the further air flow is arranged to be turbulent.

23. A method of operating a radiant tube according to claims 19, 20, 21 or 22 in which the tertiary air flow can be provided by disrupting the smooth secondary air flow by means of a baffle or the like.

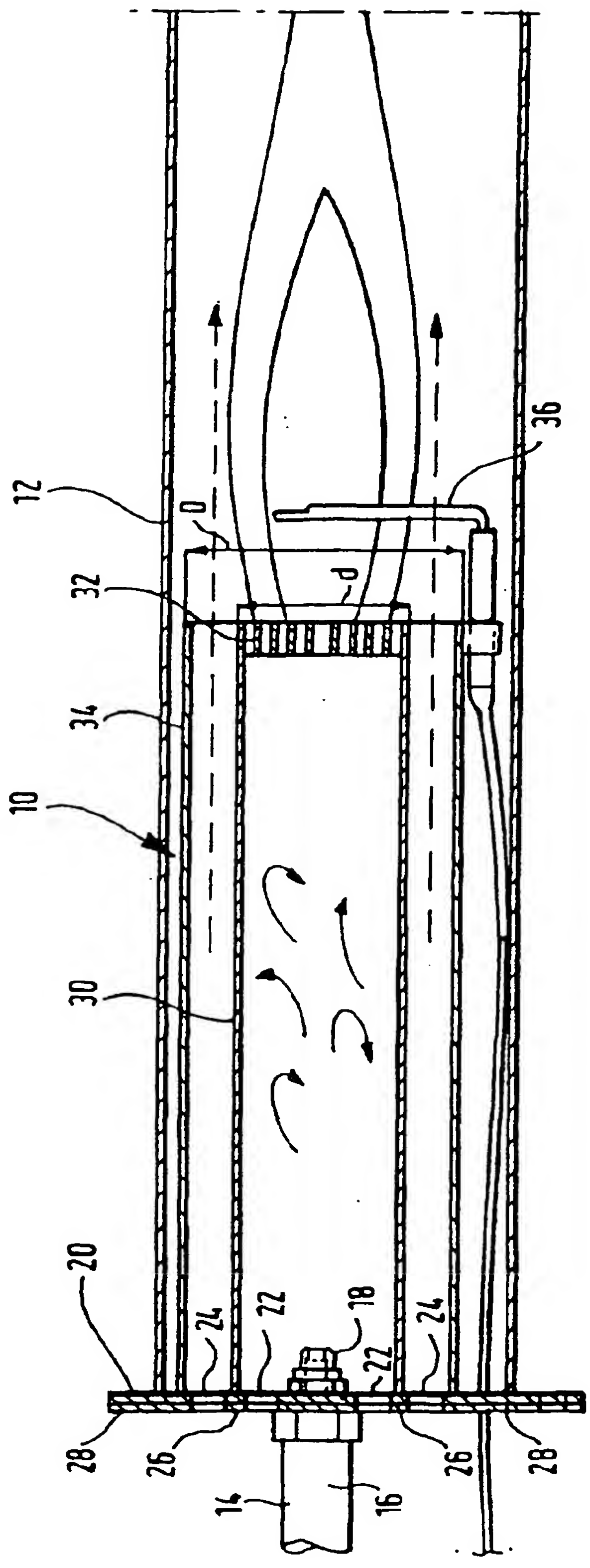

FIG.1.

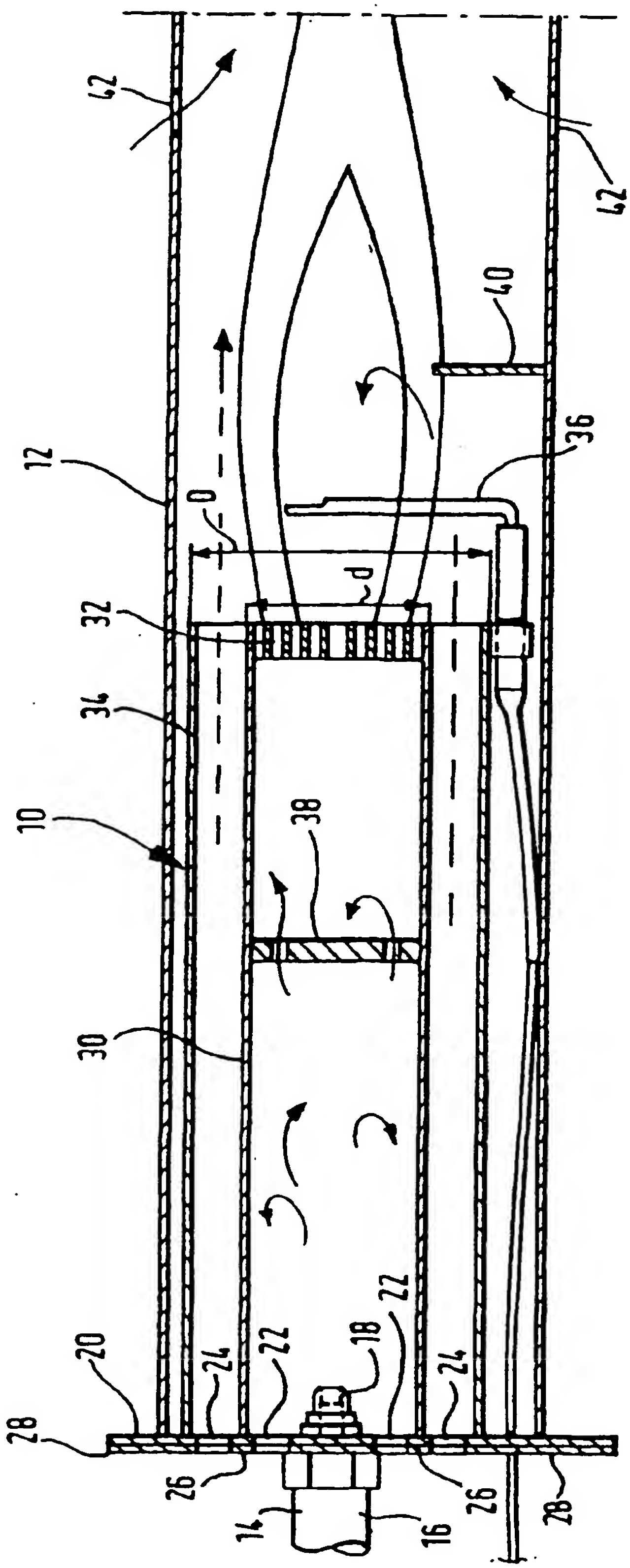

FIG.2.